Augmentative and Alternative Communication: The Role of Broadband Telecommunications

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Abstract—**This paper explores a number of the communication advantages offered to nonspeaking disabled people by the advent of broadband telecommunications. The first section of the paper focuses on text messages created by the disabled person alone. Several different word-prediction techniques, employed by nonspeakers who find difficulty in typing at computer keyboards, are experimentally evaluated. The second section of the paper concentrates on text messages created by the disabled person in collaboration with a communication partner. It is shown that existing word-prediction technologies can be enhanced by allowing prediction algorithms to take input from both ends of a telecommunication-based "conversation." More radically, it is also demonstrated that telecommunications may successfully generate new word and phrase prediction strategies by allowing communication partners at a remote site to aid an AAC user in the creation of a text message. The third section of the paper focuses on graphical and video signals. Collaboration between two people in the use of graphical icons via broadband telecommunications is demonstrated and shown to be as successful as face-to-face collaboration. A comparison of the impact of communicating via graphical icons and photographs is made. Finally, some limitations of video-based nonverbal signalling for nonspeaking people are discussed.**

I. Introduction

COMPUTER-BASED systems are now available which offer enhanced possibilities of communication to people who cannot speak. Currently, these Augmentative and Alternative Communication (AAC) devices, which allow the user to produce spoken or printed verbal messages, are based upon "stand-alone" personal computers [1]. However, throughout Europe in the 1990's, there will be a range of new developments in broadband telecommunications relying on computer-based communication terminals sited within the home [2]. Users of AAC devices may benefit from such advances since broadband telecommunications allow for simultaneous transmission of both textual data services and audio-visual services. Employing broadband telecommunications, an AAC user's text messages could be transmitted to a communication partner at a remote site and these could be accompanied by graphical and/or video signals.

A simulation of such a broadband communication service has been implemented at the University of Dundee. The system comprises a pair of communication terminals located at different sites. It allows users to communicate by voice, by sending text messages and by means of graphical icons. A high-quality video link is also provided. Using this emulation of a broadband telecommunications system, a series of experiments have been carried out to assess the potential which is offered to nonspeaking disabled people by broadband telecommunications. These experiments have focused on three areas:

1) whether traditional "stand-alone" communication devices for nonspeakers generating text output offer useful models for broadband text-messaging systems;
2) whether the unique capacities of simultaneous telecommunications links can be used to produce innovations in text-messaging aids for nonspeakers; and
3) whether the addition of graphical and video signalling is a useful communication alternative to the sending of text messages.

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II. Stand-Alone Text Messaging AAC Systems and Broadband Telecommunications for the Disabled

The primary function of text-telephones, available since 1964 [3], is to allow people with speaking and/or hearing impairments the same sort of benefits which ordinary telephone use provides for the nondisabled. They function by allowing users to communicate via text messages over the telephone network. The availability of text-messaging to the disabled will increase as computer-based terminals replace the traditional telephone within broadband communications systems. However, one problem with this type of text-based communication is that many people with speaking difficulties also suffer from forms of motor impairment which severely reduce their typing abilities. In consequence, text-telephone "conversations" for such people will be very slow affairs, which means that time-related charges for such telecommunication services will be high, while levels of fatigue and frustration may prove to be unacceptable for the motor-impaired user. In addition, slow rates of input may have adverse social effects: able-bodied communication partners may find it difficult to allow disabled people an appropriate level of control of the conversational interaction.

One approach to this problem is to incorporate into text-telephones the sort of word-prediction facilities which are currently available on stand-alone AAC devices. For example, there is already evidence that, for stand-alone personal computer-based word processors, the Pal word-prediction system can improve on character-per-keystroke rates for very

slow users by employing word frequency and recency statistics [4]. Pal—the Predictive Adaptive Lexicon—is a word predictive writing aid which is application and interface independent. It utilizes dictionaries of up to 7000 items to predict words after a user has typed in an initial letter at the keyboard. The user may then select one of five predicted words by another keystroke. Recently, work has been carried out at the University of Dundee [5] to show that similar systems can be employed with text-telephones within simulated broadband environments.

However, early pilot studies in this area also show that greater access to communication for disabled people can present the researcher with seemingly contradictory effects. When using the Pal word-prediction system to create text, subjects find the typing of messages relatively easy. This encourages some subjects to produce more text in a single session. It also encourages them to be more "adventurous" in their writing. The subject's range of words increases (with longer and more difficult words being included in the subject's vocabulary) and grammatical constructions become more complex. So Pal encourages some users to produce text which is more like that of normal, literate adults. However, this move towards more adventurous text construction may be accompanied by a greater number of errors in the spelling of single words and in the syntactical combination of those words. As Pal encourages subjects to communicate by writing more complex texts, their literacy limitations become more obvious.

In one respect, this may not be seen as a problem. Many therapists will argue that it is more important that clients be encouraged to communicate through writing than that they be taught to avoid making spelling or grammatical errors. It is obvious, however, that increases in this communication ability without concurrent increases in spelling or grammatical errors would be preferable. To this end, further developments in the Pal application are now underway.

One such development was the introduction of syntactical rules to the predictive algorithms Pal uses [6]. This revised form of Pal—SynPal—functions in the same way as Pal by presenting a number of word predictions to the user who may select an entire word from the predicted list by a single keystroke. Unlike Pal, in SynPal word prediction is based not only upon recency and frequency, but also on information gained from a complete syntactic parse of the partial sentence as it is typed by the user. The goal was to produce word predictions which were more pertinent to the user in the context of the text generated. This was achieved by predicting words which were more likely to fall into the grammatical class required by the user than the predictions of the original Pal system.

To examine the usefulness of including syntactic information within Pal's prediction routines, a long-term comparative study was undertaken. An initial prediction was that among people who have shown little improvement in writing abilities under ordinary conditions, both Pal and SynPal will encourage increases in text production. A second prediction was that the possible concomitant increases in spelling and grammar errors associated with such increases would, in some cases, be relatively small when people used SynPal, because SynPal is more likely to offer as predictions words which belong to the desired syntactic class. This should increase the likelihood that people will select directly from the prediction window. This, in turn, precludes spelling errors and, given SynPal's grammar-rule basis, promotes correct grammatical usage.

In order to test these predictions, two nonspeaking disabled subjects were asked to use Pal over an extended period of time. The first subject, IM, was a wheelchair-bound 10-year old boy suffering from muscular dystrophy. The second subject, MT, was a nonvocal 12-year old girl who has cerebral palsy. The analytic design chosen was a two-subject adaptation of the single case "A–B" approach described by Barlow and Hersen [7], with a second subject being introduced to counter some of the problems raised by confounding variables [8].

Over periods of 30 and 40 months, respectively, 62 samples of IM's written communications and 90 samples from MT were gathered. Both samples were divided into two: an "early phase" represented by the period from the first sample to the midpoint sample, and a "late phase" from the midpoint sample to the final sample. Three measures were collected from each subject within the two periods:

1) average number of words generated per writing episode;
2) average number of spelling errors per writing episode; and
3) average number of grammatical errors per writing episode.

The results of this study show that, as predicted, both forms of the Pal software encouraged subjects to communicate through larger texts. IM, who used only standard Pal throughout the observation period, produced an average of 60.5 words per writing episode during the early phase of observation and an average of 87.7 words in the late phase of observation. MT, who used Pal during the early phase and switched to SynPal in the late phase, produced an average of 43.4 words per writing episode in the early phase and 66.3 words in the late phase. For both IM and MT, the differences in output between the early phase and the late phase were shown by t-test to be significant with $t = 3.2$, $p < 0.01$ and $t = 3.7$, $p < 0.01$, respectively. So, in comparison with the early phase of observation, both subjects displayed a significant increase in the average number of words generated per writing episode in the late phase.

In accord with the second prediction, it was also noted that as IM's text output (produced throughout with the aid of ordinary Pal) increased per episode, so did the number of grammatical and spelling errors made. In the early phase, IM made an average of 1.5 grammatical errors and 0.6 spelling errors per writing episode, but these increased to averages of 3.1 grammatical errors and 2.5 spelling errors during the late phase. t-tests showed both increases to be significant, with $t = 2.9$, $p < 0.01$ and $t = 2.7$, $p < 0.01$, respectively.

In contrast, MT (who switched during the later phase to SynPal) showed no tendency to increase grammatical or spelling errors as amounts of text produced per episode increased.

Fig. 1 shows that, in comparison with the early phase of observation, IM, who used only ordinary PAL throughout, displayed a significant increase in the average number of

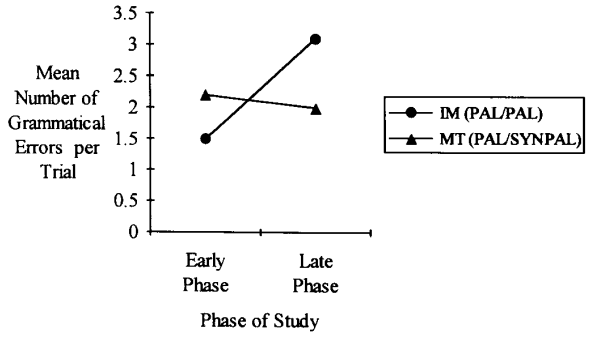

Fig. 1. Differences in grammatical error rates.

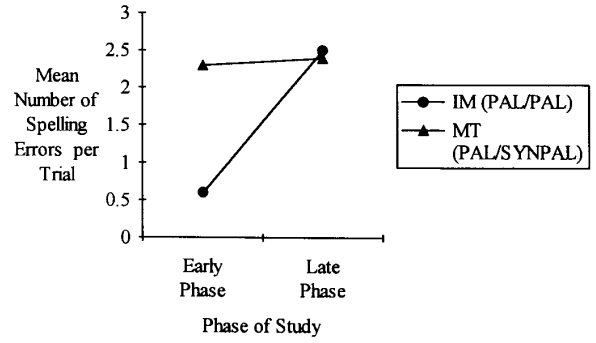

Fig. 2. Differences in spelling error rates.

grammatical errors generated per writing episode in the late phase. In contrast, MT, who switched to using SynPal in the late phase, displayed no tendency towards a greater rate of average grammatical error per episode in the late phase.

Fig. 2 shows that, in comparison with the early phase of observation, IM, who used only ordinary PAL throughout, also displayed a significant increase in the average number of spelling errors generated per writing episode in the late phase. In contrast, MT, who switched to using SynPal in the late phase, produced, on average, significantly fewer spelling errors per episode in the late phase.

These results provide some preliminary evidence that inclusion of word prediction facilities may boost use of text-messaging systems such as text telephones by disabled people. They also reveal that the very success of such systems can create ancillary problems leading to an increase in spelling and grammar difficulties which could have adverse communication consequences. The introduction of SynPal, however, shows that at least some of these difficulties can be overcome. Of course, given the limitations of single case experimental designs, these conclusions are, at most, tentative.

III. Innovations in Text Messaging Based Upon Simultaneous Telecommunication

The preceding section discussed some of the issues associated with introducing to text-telephony the word prediction techniques being developed in stand-alone AAC devices. However, the advent of computer-based text messaging via telecommunications also allows for a more radical form of text-prediction. The stand-alone AAC device employing predictive techniques is limited to relying solely on previous text input by the user. A telecommunications-based text messaging device offers the opportunity for prediction techniques which utilize text which is input from both ends of the communication interaction. To examine these opportunities, several experiments were conducted using the simulated broadband system's text-message carrying data channel.

TABLE I
Key-Saving Percentages When Using One-Way and Two-Way Pal Text Prediction

Subject	Size of Dictionary at Start (Number of Words)	One-way Pal adaptation	Two-way Pal Adaptation
a	0	18	27
b	0	6	18
c	5000	39	43
d	5000	41	38

In a preliminary evaluation of this form of "two-way" text-prediction, a version of the Pal prediction system was designed in which the Pal predictive system was allowed access to both participants in a text dialog carried out across the simulated broadband network. It was anticipated that accuracy of predictions obtained would tend to rise whenever recency and frequency statistics employed by the Pal system were capable of being updated from both ends of the text "conversation" simultaneously. Since the Pal system can utilize a built-in dictionary, consideration was given to the issue of dictionary size. It was predicted that possible benefits derived from predictions based on two-way prediction will be maximal where users have relatively small built-in dictionaries.

Subjects were four able-bodied university students with no prior experience of Pal, who formed two communication pairs (a, b and c, d). In a within-subjects, counterbalanced design, two "free" conversations lasting 30 min were conducted by each subject. In each pair, one subject used standard Pal, while the other used a version of Pal adapted to collect text from both partners' inputs. Subjects a and b started both conditions of the experiment with an empty prediction lexicon. Subjects c and d started both conditions of the experiment with a large prediction lexicon.

Results showed (see Table I) that both subjects who began with an empty Pal dictionary derived greater benefits from the Pal prediction system, as measured by the key-savings produced by Pal when Pal collected information from both ends of the "conversation." Moreover, even with a large dictionary already present, a third subject showed a similar improvement.

The "two-way Pal" predictive system employed in this preliminary evaluation retained the overall text-prediction strategy employed by the original, stand-alone version of Pal. However, recent developments in the field of computer-based collaborative writing techniques show that people are able to work jointly in the creation of a single text by communicating

via broadband networks. In a number of studies [9], [10], coauthors have been seen to collaborate simultaneously across a number of different sites in order to create a single document. This possibility opens the way for more radical forms of helping disabled people to input text which rely on the collaborative effort of both telecommunication partners.

To test whether collaborative writing techniques could be adapted to provide help for the disabled in creating text messages, an experiment was designed in which pairs of subjects were again asked to communicate using text messages across the network. In this experiment, a simple collaborative writing tool was designed which made available to a disabled partner all of the input entered at the "conversational" partner's keyboard. This allowed the disabled user to "capture" the communication partner's text and use it to create further messages. It was hypothesized that such a system would present keystroke-per-character savings for the disabled partner. It was also hypothesized that users would find the system to be more "learnable" than traditional word-prediction techniques such as Pal. In the collaborative setting, all of the partner's text contributions should be semantically relevant, whereas predictions from traditional systems such as Pal, based merely on statistical measures, can include words which are semantically unrelated to the current "conversation" topic, which the inexperienced can find confusing. Previous work has shown that, because of this, people require some training on systems such as Pal before they are able to employ them properly. The second hypothesis was that this training requirement would not show up to the same extent in the collaborative condition. To check for this, the experimental sample was made up of novice users who had no previous experience of predictive systems and who would be most likely to be sensitive to a lack of training.

Subjects were 12 able-bodied university students, half of whom—the "disabled" subjects—simulated a form of motor impairment by typing at the keyboard using a stick held between the teeth. None of the subjects had previous experience of the Pal prediction system or of "collaborative writing" via linked terminals. Subjects were placed in separate rooms and provided with terminals to the broadband system, with only the text-messaging channel left open. Using a "within-subjects," counterbalanced design, they were asked to create five messages using the Pal prediction system and five using the "collaborative writing" system. In the "solo" Pal condition, the disabled subject could see both his/her own text and the partner's text in a pair of text windows. In the "collaborative" condition, text from the disabled subject and the communication partner appeared in a single, communal text window. In the collaborative condition, the disabled subject's partner was asked to try to help the disabled person by predicting the word or phrase the disabled person was trying to type and completing it for him/her. Data collected included keystroke-savings (where for each message keystroke-savings = (number of characters − number of keystrokes)/number of characters, expressed as a percentage).

The results showed that collaborative writing techniques can be used to provide aid to disabled people in the creation of text messages. Collaboration with the communication partner produced, for the disabled person, an average keystroke-per-character saving of 22.2%. The second hypothesis, that such savings could be gained easily in comparison with traditional text prediction systems, was also confirmed. The subjects, having had no training period in using the predictive software, were able to make little use of the traditional prediction system in the "solo" Pal condition, displaying an average keystroke-per-character rate of only −3.7% (The negative sign reflects the fact that subjects in the "solo" Pal condition sometimes wrongly selected predictions and had to use the backspace key to erase them.). A t-test revealed this difference in percentage savings between the "collaborative" and the traditional "solo" conditions to be significant ($t = 5.8$, $p < 0.01$).

These results show that a disabled person who is unable to type messages normally may gain benefit from working in collaboration with a communication partner across a broadband telecommunications link which allows for transfer of text messages. Ease of learning suggests that people found the collaborative form of text generation aid to be a natural form of interaction. Moreover, a survey of all 12 users conducted at the end of the experiment revealed that 75% of the subjects found the collaborative system to be more enjoyable than the traditional system. This may reflect the additional social benefits which accrue when people work together on a common task.

IV. The Addition of Graphical and Video Signalling to Broadband Telecommunications for the Disabled

Broadband telecommunication systems will offer audio-visual services in addition to data services such as text messaging [11]. This raises the possibility that disabled people communicating via such systems may be able to enhance or replace the verbal content of text messages with nonverbal information composed of graphics or video signals. To evaluate these possibilities, several experiments were conducted using graphical icons, still photographs, and simultaneous video links.

In the first of these, a task was designed to emulate aspects of an interaction between a speech therapist and a nonspeaking client where therapist and client are working together to compose messages made up of nonverbal graphical icons. This is a common situation when nonspeaking clients have little or no verbal ability and must communicate by means of pictorial languages, such as the Picture Ideogram Communication Signs system, the Bliss symbol system, or the Makaton language [12]. In the experimental task, subjects were asked to complete a visual puzzle by jointly manipulating a set of picture icons. Using a counterbalanced, within-subjects design, six pairs of subjects completed this task in two conditions: using the simulated broadband telecommunications system (the "Telecomms" condition) and working together in the same room (the "Same Room" condition). The experimental goal was to assess whether this sort of task, whose clinical analog is traditionally accomplished by having a therapist present with the client, could be as easily managed remotely by means of the broadband link.

Subjects were able-bodied university students who had no prior experience of the puzzle task. A measure of task success was formulated which compared the state of the puzzle at the end of the time allotted to subjects with the final "all-correct" solution state for the puzzle. A ratio of number of correct final placements against total number of placements was calculated for each of the experiment's six communication pairs. The results showed a mean ratio of 0.88 for the same room condition and 0.76 for the telecommunications condition which, as measured by t-test, was not a significant difference between the two conditions ($t = 0.9$, $p > 0.05$). Subjects were able to jointly work as well in solving the graphical icon puzzle when communicating via the broadband link as in the same room condition. This suggests that graphical communication across broadband telecommunications links may be a possibility even for those who are not able to make use of the verbal information carried by text messages.

Although this preliminary result indicates the potential usefulness of graphical communication channels in a broadband environment, there is evidence to suggest that some types of message may be harder to convey by means of symbols than others—especially those which involve an emotional content. To examine whether this might be a potential limitation for broadband communications, a second experiment was devised in which subjects were asked to pass emotional and nonemotional messages by means of graphical images.

Subjects were eight able-bodied university students. A set of 64 symbols was devised, comprising line drawings and photographs. Twenty symbols were designed to be emotionally expressive. The "emotional" line drawings were drawings of faces expressing a variety of emotions. The "emotional" photographs were of a professional actress' face displaying the relevant emotion. The symbol sets were incorporated into a broadband telecommunication system. Using a within-subjects, counterbalanced design, subjects were asked to use the symbols to send messages to a communication partner located in a different room. In each pair of subjects, one member was asked to translate 10 short statements into the graphical symbol equivalent. The 10 statements in total used 24 symbols. This graphical "translation" could be viewed by the other member of the pair using the terminal located in the other room. The other member was then asked to translate the messages received into their English language equivalents. The measurement consisted in the number of symbols correctly "translated" by each partner acting as message sender and as message receiver. Since the 10 messages were composed in total of 24 symbols, and each partner both sent and received 10 messages, each subject could potentially score 48 correct symbol translations—24 during the message-sending part of the experiment, and 24 during the message-reception part.

The results, as measured by the average number of messages correctly interpreted by communication partners, showed that subjects found emotion-laden symbols harder to utilize than nonemotional symbols. On average, 38.7 emotion-laden symbols were correctly translated while an average of 43.6 nonemotional symbols were correctly translated. A t-test revealed this to be a significant difference, with $t = 3.24$ and $p < 0.01$. A separate test revealed no difference between the use of line drawings and photographs in ease of translation for either emotional or nonemotional symbols. What these results indicate is that for some types of interaction where people are discussing emotional matters, face-to-face communication may still offer advantages over communication by means of broadband telecommunications.

Since most evidence points to the fact that nonverbal signals are especially useful for communicating emotional content [13], it was decided to extend the communication channels available to subjects by allowing them to use the simultaneous video link. It was hypothesized that the poor performance of graphical and still pictures across the broadband link might be improved if subjects could see one another's facial expressions instead. However, the subsequent evidence did not support this hypothesis. An experiment was designed in which pairs of subjects communicated across the simulated broadband telecommunications link. Some pairs of subjects included a nonspeaking disabled subject who typed text messages with the aid of a mouth-stick, and some pairs did not. All subjects were university students and the design was a between-subjects design. It was assumed that able-bodied communication partners would try to use the video channel to gather nonverbal information from disabled partners. This generated two hypotheses:

1) When a communication pair included a nonspeaking disabled partner, the *number of times* the able-bodied partner looked towards the video channel output would be greater than in cases where neither partner was disabled.
2) When a communication pair included a nonspeaking disabled partner, the *duration of each occasion* the able-bodied partner looked towards the video channel output would be longer than in cases where neither partner was disabled.

Video-recordings were made of 10 pairs of subjects communicating across the broadband link. The number and duration of occasions on which each partner fixed his or her gaze on the computer screen window carrying the video output showing the partner's face was measured. The results showed that when one partner was disabled, the mean number of times the nondisabled partner looked at the video channel output was 5.2, while the mean number of times was 6.8 when neither partner was disabled. A t-test showed that, with $t = 1.63$, this was not a significant difference ($p > 0.05$).

So the video results showed that communication partners of a disabled subject did not look at the video output significantly more than people whose partners were able-bodied. Moreover, there was a significant difference across the two conditions in the average length of the occasions during which the video signals were surveyed.

As Fig. 3 displays, the average duration of an episode of looking at the video output for people with disabled communication partners was 65 sixtieths of a second. This is approximately half the average duration of a looking episode of those whose partners were not disabled—152 sixtieths of a second. A t-test revealed this to be a significant difference between the two conditions, with $t = 3.21$ and $p < 0.01$. This

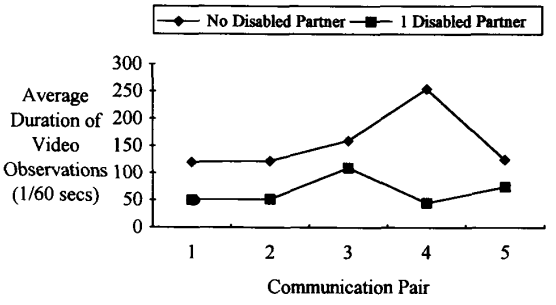

Fig. 3. Effect of having a disabled partner on average duration of occasions when the video output is surveyed.

difference suggests that for certain types of task and certain disabled users, provision of simultaneous video gives little added benefit.

Fine grain analyses of the video recordings suggest a possible reason for this finding. In order to produce text messages, disabled subjects were forced to spend most of their time looking at the terminal keyboard. This meant that their partners, on glancing at the video output window, often found themselves looking at the top of the disabled person's head. This provided a disincentive for partners of disabled subjects to use the video channel.

V. Conclusion

This series of experiments has focused on aspects of interpersonal communication likely to arise in broadband networks. In terms of potential benefits to nonspeaking disabled people, these experiments have yielded mixed results. It is clear that broadband networks offer valuable communication facilities for disabled people, but in certain cases, enabling access to these facilities is problematic. Simply providing multimedia communication facilities is not a panacea; multimedia components must be carefully selected by taking task and disability into account. In particular, the results presented here demonstrate two key directions for future research:

- the development of AAC techniques for improving the rate of text production in broadband text-messaging systems; and
- the relevance and presentation of video for nonspeaking disabled users must be comprehensively investigated.

In relation to the first of these points, the experimental evidence presented here suggests that text messaging is a valuable future communication medium for nonspeaking disabled people. Such systems will be able to benefit from existing developments in text production now underway in "stand-alone" AAC computer-based devices. Moreover, the advent of broadband telecommunications may also allow for novel forms of augmentative and alternative communication in which communication partners can jointly work together in recording textual information.

The future benefits of graphical and video communications are, however, more ambiguous. In some tasks, communicating with graphical icons seems to be as efficient across a broadband link as graphical communication in a face-to-face setting. However, remote communication seems to be less successful for those types of interaction which involve emotional messages. And this finding seems to hold both for simple iconic communication and for interaction by way of still photographs. This shows that there is a clear need for further research in the representation of emotion for this type of communication.

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